APHIS Risk Analysis on Importation of Foot and Mouth Disease (FMD) Virus from Surrey County, England, in the United Kingdom

United States Department of Agriculture
Animal and Plant Health Inspection Service
Veterinary Services
National Center for Import and Export
Regionalization Evaluation Services

March 2008

Table of Contents

Executive Summary

On August 3, 2007, the United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA) reported a case of foot-and-mouth disease (FMD) in Surrey County, England. Over the next eight weeks, a total of eight FMD outbreaks were confirmed in the United Kingdom (UK), all located on premises in Surrey County. The last FMD outbreak in the UK was confirmed on September 30, 2007 [1].

Prior to August 3, 2007, APHIS recognized all of the UK as free from FMD, allowing the UK to export ruminants and swine and the fresh meat and other animal products of ruminants and swine to the United States. However in an effort to help prevent the introduction of FMD into the United States, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) immediately responded by administratively prohibiting the importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from the UK, which includes England, Scotland, Wales, and Northern Ireland. On August 17, 2007, APHIS lifted trade restrictions imposed on Northern Ireland as a result of the outbreak in Surrey County as Northern Ireland had provided information which led APHIS to conclude that exports from Northern Ireland did not pose an FMD risk.

In the months that followed, DEFRA and the European Commission provided APHIS with frequent updates of the findings and actions taken leading APHIS to conclude that it was unlikely that the disease had spread to other areas of Great Britain outside of Surrey County, England. Therefore, on January 30, 2008, APHIS published an interim rule removing only Surrey County from the list of regions recognized as free of FMD [2]. The effect of this action was to limit APHIS' restrictions to Surrey County and allow trade to resume from the rest of Great Britain.

In the interim rule, APHIS recognized that the UK immediately responded to the detection of the disease by imposing movement restrictions to prevent the spread FMD and initiating measures to eradicate the disease. The interim rule also stated that because of the UK's efforts to ensure that FMD did spread beyond its borders, APHIS would reassess the situation at a future date. The future reassessment would determine whether it is necessary to continue to prohibit imports from Surrey County, England. Of particular relevance to this reassessment is the Surrey County's response to the FMD outbreaks; the source of these outbreaks; and the measures that have subsequently been implemented to prevent a reoccurrence of FMD in the region previously recognized as free of FMD.

APHIS cites the prompt actions by the UK veterinary authorities to control animal movements and to aggressively conduct epidemiological investigations as factors in limiting the spread of disease. The surveillance programs conducted in response to the outbreaks indicate that the diseased animals are not likely to exist in Surrey County, England. The implementation of corrective measures at the Pirbright laboratory and vaccine production center, the identified source of the virus responsible for the Surrey

County outbreaks, as well as the enhanced biosecurity awareness and inspection programs at laboratories throughout the UK, give APHIS confidence that the risk of accidental release of live virus into the environment has been appropriately addressed.

APHIS concludes that the eradication and control measures undertaken by the UK in response to the 2007 outbreaks were effective and that FMD-infected animals are not likely to exist in Surrey County, England. APHIS could identify no additional risk factors currently applicable to consideration of Surrey County, England as FMD-free. Therefore APHIS considers the risk of introducing FMD into the United States with the resumption of importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England to be low.

Regarding the likelihood of exposure, APHIS considers three likely pathway of exposure of domestic livestock to FMD virus: the feeding of FMD virus -contaminated food waste to swine, contact with imported infected live animals, and contact with infected genetic material. Based on the unlikely prospect that FMD-infected animals exist in Surrey County, England and on the mitigating effects of waste feeding and import regulations associated with these pathways, APHIS concluded that the likelihood of exposure from importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England to be low.

APHIS considered the potential effects of an FMD outbreak on animal and public health, as well as associated economic impacts. Consequences of human exposure from FMD are negligible. Conversely consequences on animal health are high, although effective disease surveillance and control measures could reduce the consequences by reducing the extent of spread. Effects on the environment have been considered in separate reviews in compliance with applicable federal environmental laws and regulations; however, consequences to the environment are considered to be within the scope of APHIS resources and authority to manage adequately.

Although consequences of an FMD outbreak are potentially substantial, the likelihood of an outbreak occurring from exposure of the domestic ruminant and swine populations to ruminants and swine and the fresh meat and other animal products of ruminants and swine imported from Surrey County, England is low.

In summary, APHIS concludes that the risk of introducing FMD into the United States with the resumption of trade in ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England is low.

Introduction

On August 3, 2007, the United Kingdom's (UK's) Department for Environment, Food and Rural Affairs (DEFRA) reported a case of foot-and-mouth disease (FMD) on a beef finishing farm near Guilford in Surrey County, England [1]. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) immediately notified DEFRA that it was prohibiting the importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from the UK. At the same time, APHIS issued an alert to the Department of Homeland Security's Customs and Border Protection officials at U.S. ports of entry banning the importation of susceptible animals and related commodities from all of the UK, which includes England, Scotland, Wales, and Northern Ireland.

On August 17, 2007, APHIS announced that it was lifting trade restrictions imposed on Northern Ireland as a result of the outbreak in Surrey County. Northern Ireland had provided information to APHIS documenting that officials took immediate steps to close their borders and prevent the introduction of FMD. In addition, agricultural officials in Northern Ireland traced all FMD-susceptible livestock imported from Great Britain in the days leading up to the outbreak. These animals were identified, placed under movement restrictions, and inspected. No clinical signs suggestive of FMD were detected in any animals, and none of the animals were imported from the County where the outbreak occurred.

In the months that followed, DEFRA and the European Commission provided APHIS with frequent updates, often on a daily basis, of the findings and actions taken. In total, 8 infected premises were identified between August 3 and September 30, 2007. All of these were located in Surrey County, and it became increasingly evident from DEFRA's intensive surveillance efforts that it was unlikely that the disease had spread to other areas of Great Britain.

Therefore, on January 30, 2008, APHIS published an interim rule removing only Surrey County from the list of regions recognized as free of FMD [2]. The effect of this action was to limit APHIS' restrictions to Surrey County and allow trade to resume from the rest of Great Britain. In the interim rule, APHIS recognized that the UK immediately responded to the detection of the disease by imposing movement restrictions to prevent the spread FMD and initiating measures to eradicate the disease. The interim rule also stated that because of the UK's efforts to ensure that FMD did spread beyond its borders, APHIS would reassess the situation at a future date. The future reassessment would determine whether it is necessary to continue to prohibit imports from Surrey County, England.

On January 23, 2008, a small team of APHIS officials met with DEFRA counterparts in London to gather additional information on the outbreak and the measures taken following the last reported case in September. The information obtained during that meeting enabled APHIS begin its reassessment.

Objective

The objective of this review is to examine events that occurred during and after the outbreak and to evaluate the risk associated with the resumption of importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England, UK. The results will provide the basis for APHIS to decide whether to recognize Surrey County, England as free from FMD without vaccination.

The risk analysis was based on information from several sources. The European Commission (EC), on behalf of DEFRA, provided information to APHIS regarding the 2007 outbreaks of FMD in Surrey County. Information obtained from DEFRA's website [3] and during the APHIS team visit to DEFRA headquarters in London on January 23, 2008 [4], related European Commission (EC) Decisions [5], and reports to OIE [1] constitute the supporting documentation for this evaluation.

The UK, as a Member State of the European Union (EU), is obligated to comply with the provisions of Council Directive 2003/85/EC which describes the measures for the control and eradication of FMD [5]. These measures are harmonized and binding throughout the EU serving as an important means to prevent the introduction and spread of FMD within the EU as well as to prevent the spread of FMD to other countries through its export market. The Commission has the authority to conduct periodic evaluations to verify Member State compliance.

Some important provisions required by Council Directive 2003/85/EC are: the compulsory notification of suspected cases of FMD; animal identification and records of movements; depopulation of all animals of susceptible species on holdings where FMD is confirmed or likely to have been exposed; cleaning and disinfection of affected premises; establishment of protection and surveillance zones around affected holdings to enforce movement controls; epidemiological investigations; a national laboratory in each Member State and a Community reference laboratory for FMD diagnosis; and standards to be followed when implementing an emergency FMD vaccination program. It is important to note that emergency vaccination measures were not implemented by the UK in response to the 2007 outbreaks in Surrey County, England. In fact vaccination against FMD has never been carried out in the UK. The evidence listed above provided the means for APHIS to evaluate the effectiveness of the UK's implementation of Council Directive 2003/85/EC in response to the series of FMD outbreaks in Surrey County, England during 2007.

Hazard Identification [6-8]

Hazard identification is defined by the World Organization for Animal Health (OIE) as "…the process of identifying the pathogenic agents which could potentially be introduced in the commodity considered for importation", and is a critical component of an import risk analysis. APHIS identified several animal diseases listed by the OIE that pose primary hazards associated with initiating trade in animals and animal products from foreign regions. The listed foreign animal diseases of primary concern are addressed specifically in APHIS regulations.

The hazard identified for the Surrey County, England, in this assessment is the FMD virus, and is recognized by APHIS as a hazard of primary concern. In this regard, before opening or, as in this case, resuming trade in animals and animal products with a region or country known by APHIS to have been affected with FMD, APHIS conducts an import risk analysis to support rulemaking.

This risk analysis considers the risk of introducing FMD virus into the United States through the importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from the Surrey County, England. Epidemiological characteristics of the agent relevant to the import risk it might pose are described in the Appendix.

Risk Analysis

This analysis is composed of four components: the release assessment, the exposure assessment, the consequence assessment, and the risk estimation. These components are defined in OIE guidelines and represent the internationally recommended components for animal health import risk analysis [9].

Release Assessment

For the purpose of this report, release assessment refers to the likelihood that FMD exists in Surrey County, England and, if so, how likely it would be for the disease to be introduced into the United States through importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England. The likelihood will depend on the effectiveness of the eradication and control measures undertaken by the UK in response to the 2007 outbreaks of FMD.

In prior years, the UK reported an FMD epidemic in 1967-1968, a single case in 1981, and an extensive epidemic in 2001. A total of 2,030 cases of FMD were confirmed

between February and September, 2001. Those cases were the subject of previous APHIS evaluations of the FMD status of the UK [10, 11]. In August and September, 2007, the UK reported a series of eight outbreaks in Surrey County, England which lead to the current import restrictions imposed by APHIS. The following information describes the 2007 outbreaks.

FMD in Surrey County, England in 2007

The outbreak occurred in two clusters and involved a total of 8 premises. The outbreak history and epidemiology are described below, as well as the tracings conducted to identify premises that might have been exposed to the virus prior the establishment of movement restrictions. We also describe the surveillance that was carried out to determine if the outbreak had spread and to subsequently demonstrate freedom from FMD. Finally, we discuss investigations into the source of the outbreak and measures taken to prevent a reoccurrence.

History of the Outbreak

August Outbreak Cluster: Chronology of Events

August 3, 2007

On August 3, 2007, DEFRA reported positive test results for FMD on a beef finishing farm near Guilford in Surrey County, England. An outbreak of FMD was officially declared, and control measures consistent with European Community legislation (Council Directive 2003/85/EC) [5] were immediately implemented. A protection zone of three kilometers radius and a surveillance zone of 10 kilometers were established around the farm, and authorities began depopulating the infected premises. In addition, a movement ban was imposed on all ruminants and pigs in England, Scotland, and Wales.

August 4. 2007

The culling of the cattle on the infected premises was completed on August 4. This included the 38 cattle known to be infected, and 26 cattle on two additional sites under the same ownership and management. The cattle on these two sites, located within the protection zone, showed no clinical signs of FMD but were culled in line with standard procedures and tested. One of the additional animals tested positive for FMD. Together, these three sites were considered a single epidemiological unit and were later designated as Infected Premises 1 (IP1).

Two dangerous contact premises were identified adjacent to the IP1 sites. One premises contained 8 sheep, 2 goats, and 9 pigs, and the other housed 14 cattle. Both premises were depopulated. Samples taken from all of the animals were negative for FMD.

The virus involved in the outbreak was identified as an FMD strain 01 BFS67-like virus. The last outbreak known to have been caused by this particular strain anywhere in the

world occurred in Great Britain in 1967. The FMD strain 01 BFS67 is most similar to strains used in international diagnostic laboratories and vaccine research and production facilities, including the UK's Institute of Animal Health (IAH), which is the Community Reference Laboratory for FMD, Merial Animal Health Ltd., a major pharmaceutical company, and Stabilitech Ltd, a small private company operating in a laboratory on the IAH premises. All three facilities are located at the Pirbright site in Surrey County, approximately 5 kilometers from the initial outbreak.

Because of the apparent association between the outbreak and the Pirbright facilities, a new single protection zone was created encompassing both the infected premises and the Pirbright site, with a single surveillance zone of 10 kilometer radius. In addition, an independent review of the biosecurity arrangements on the Pirbright site was commissioned. Results of this review are presented subsequently in this document.

August 7, 2007

On August 7, a second outbreak of FMD was confirmed. The outbreak was located in the protection zone set up around the first outbreak and involved a beef breeding, rearing and fattening enterprise with animals located on three separate sites. A total of 119 cattle were present on the three sites, all of which where depopulated. All locations were under the same ownership and management, and were considered a single epidemiologic unit designated IP2.

No dangerous contact premises were identified. However, one adjacent holding was depopulated on suspicion of FMD. This premises held 16 beef cattle, 3 sheep, 2 goats and 342 pigs. Results of laboratory testing were negative for FMD virus.

Both the first and the second outbreak were attributed to a point source of infection. A second protection zone and surveillance zone were established around IP2, with the new surveillance zone overlapping the surveillance zone established around IP1.

No additional cases of FMD were detected in August. All animals destroyed during the August cluster were disposed of by incineration and cleaning and disinfection procedures were initiated on all premises within 24 hours following depopulation.

August 24, 2007

On August 24, 14 days after the last diagnosis of FMD, the UK lifted measures in the two protection zones and merged the area of the protection zones with the area of the surveillance zones. The measures in the surveillance zone continued to apply in the merged zone.

September 8, 2007

The UK authorities lifted all measures relating to the surveillance zone on September 8. Thirty days had elapsed since the cleaning and disinfection of the last infected premises,

and clinical inspections and serological testing in the combined surveillance zone had been completed. All results were negative. Investigations into animal movements immediately prior to the outbreaks found that no at-risk live animals or animal products had moved off the infected holdings, and no at-risk animals had moved out of the protection and surveillance zones.

September Outbreak Cluster: Chronology of Events

September 12, 2007

On September 12, the UK authorities reported a new case of FMD in Surrey County, approximately 5 kilometers north of the previous outbreaks. A movement ban was immediately imposed throughout Great Britain and export certificates were withdrawn. The farm (IP3) comprised eight separate parcels of land, and a single 3 kilometer protection zone and 10 kilometer surveillance zone was established around all of them. A total of 281 cattle and 8 pigs were held on these lands. Culling of the initially affected group was completed on September 13, and depopulation of the remaining sites was completed on September 16. Laboratory tests determined that a second location on IP3 was also infected.

One holding of 24 pigs adjacent to IP3 was considered a dangerous contact premises and was depopulated on September 15. Laboratory tests on these animals were negative for FMD.

September 15, 2007

A fourth infected premises (IP4), also in Surrey County, was confirmed positive for FMD on September 15. The protection and surveillance zones established around IP3 were enlarged accordingly. This farm raised animals at two locations, one holding 54 cattle and the other 743 pigs. Depopulation was completed on September 16. Clinical findings and positive laboratory results were confined to cattle; the pigs tested negative for FMD.

Following the confirmation of infection on IP4, an outdoor pig unit was identified immediately opposite this IP and under the same ownership. The herd was depopulated on suspicion of disease and samples collected for testing. Results of testing were negative.

September 17, 2007

FMD was confirmed on a fifth premises (IP5). This premises was located within the protection zone and held 22 cattle, 16 sheep, and 2 pigs. Healing, 2-3 week old lesions had been found in 17 of the 22 cattle and 10 of the 16 sheep the previous day. All of the cattle tested positive on serology but negative on virus isolation. Twelve of the sheep were seropositive and virus negative, and both pigs, which exhibited no lesions, were seronegative and virus negative. Depopulation was completed on September 18.

September 21, 2007

FMD was confirmed on a sixth premises (IP6) which held 34 cattle at two locations, both within the protection zone. Two of the cattle at one location had 2-4 day old lesions and both were virus positive. All of the cattle were seronegative. Depopulation was completed on September 22.

September 24, 2007

A seventh outbreak of FMD was confirmed on a premises (IP7) in the protection zone. The 16 cattle on the premises were culled on September 24. Fourteen of the animals had lesions judged to be 1-4 days old. FMD virus was isolated from 15 of the animals and 2 were seropositive.

September 30, 2007

The eighth and final outbreak of FMD was confirmed on September 30. The premises involved (IP8) raised 134 cattle and 16 sheep at four locations; three were within the protection zone and one within the surveillance zone just outside of the protection zone. Eight cattle had lesions estimated to be 3-4 days old. Virus was isolated and serology was negative. All four locations were depopulated on September 30.

As a precaution, five premises located within 3 kilometers of IP8 were depopulated (161 cattle and 1 goat) following an epidemiological assessment that they were at high risk of infection. Laboratory tests were negative.

All animals destroyed during the September cluster were disposed of by incineration and cleaning and disinfection procedures were initiated on all premises within 24 hours following depopulation.

Epidemiology of the Outbreak

The virus involved in the outbreak was identified as Type O_1 BFS (British Field Strain) 1860 (FMD O_1 BFS 1860/67UK), which is a virus strain recovered from an FMD outbreak that occurred in Great Britain in 1967. This strain only exists in FMD reference laboratories and vaccine manufacturing facilities and is not known to be in circulation anywhere in the world. In Great Britain, this strain of FMD virus is used by the Institute of Animal Health (IAH), which is the Community Reference Laboratory for FMD, Merial Animal Health Ltd., a major pharmaceutical company, and Stabilitech Ltd, a small private company operating in a laboratory on the IAH premises. All three of these facilities are located at the Pirbright site in Surrey County, approximately 5 kilometers from the initial outbreak.

Epidemiological investigations into the source and spread of the outbreak led to the following main conclusions:

1. The most likely scenario for infection of IP1 is considered to be via fomite transmission resulting from environmental contamination at the Pirbright site (see subsequent discussion on source investigations).

2. The evidence for infection of cattle on IP2 suggests windborne transmission from IP1. The distance between the two premises was approximately 1.7 kilometers.

3. The age of the lesions found in animals on IP5 provided a temporal link between the August and September outbreak clusters, i.e., IP5 probably became infected in August but the infection was not detected for several weeks. The means by which the virus was introduced onto the premises remains uncertain.

4. The epidemiological evidence for the other five cases in September is consistent with local spread from IP5 and/or each other. The IPs were situated in a semi-urban area in which there are frequent movements of people and a number of farms are made up of several parcels of land with the owners and farm workers traveling between them.

Tracings from the August and September Clusters

DEFRA investigated all movements of susceptible animals that had occurred prior to the establishment of movement restrictions in August and during the brief period between the lifting of the August restrictions and the establishment of new restrictions in September. A relatively low number of movements had occurred from the protection and surveillance zones of both the August and September clusters, and the movements took place over very short distances. All known movements were traced, and if the animals were moved other than to slaughter, the recipient holdings were restricted and the animals subjected to two rounds of clinical examinations and serological testing. No FMD-positive animals were detected. All animals that had moved from infected premises prior to the detection of FMD had been sent directly to slaughter.

All other identified risk movements (e.g., personnel and vehicles) from infected premises were traced and no evidence was found of virus spread.

Surveillance

Serological testing

The testing procedures used to detect FMD antibodies included the following:

- A solid phase competition ELISA for type O antibodies (SPCE-O) developed by IAH;
- The Ceditest FMD type O (Cedi-O), a commercially available test for type O antibodies;
- The Ceditest FMD virus -NS (Cedi-NS), a commercially available test for the non-structural proteins of FMD virus;
- The virus neutralization (VN) test, used for confirmatory testing.

The testing regime called for either the SPCE-O or Cedi-O test for screening and initial retesting, then the Cedi-NS test for confirmation. Any animal found positive on both SPCE-O/Cedi-O and Cedi-NS tests was considered highly likely to be a true positive, and this was further confirmed by the VN test.

Serological Surveillance during the August Cluster

Four hundred and fifty four premises were visited in the protection and surveillance zones, and 5,767 blood samples were tested. Sampling was carried out at a level sufficient to detect a 5% prevalence within the flocks and herds with at least a 95% level of confidence.

There were 82 premises with susceptible livestock in the protection zone. Clinical inspection visits took place between August 4 and August 16, and a total of 270 visits were made, including repeat visits. No clinical signs were observed in any of the animals. Blood samples were taken from 1,606 sheep and goats on 55 of the premises. All of these animals tested negative. A final clinical inspection visit was made to all premises in the protection zone by August 23.

In the surveillance zone, there were 372 premises with susceptible livestock. All of these premises were visited between August 30 and September 4, and blood samples were taken from 4,161 animals. All tested negative for FMD antibodies.

Serological Surveillance during the September Cluster

Following the detection of a new infected premises (IP3) on September 12, new protection and surveillance zones were established around the infected holding and were adjusted following confirmation of FMD on IP4 to IP8.

Surveillance activities in the protection zone were similar to those conducted during the August cluster, but were modified to intensify surveillance in cattle. To increase the likelihood of detecting infection in cattle, emphasis was placed on targeted and thorough inspections and sampling of cattle in an area within the protection zone designated the Intensive Patrol Area. In this area, cattle were clinically inspected every day and sampled for polymerase chain reaction (PCR) testing every second day.

There were 88 premises with susceptible livestock within the September protection zone. The total number of susceptible animals included 4,322 sheep, 91 goats, 1,616 cattle, and 1,429 pigs. Serologic testing of sheep and goats on all premises was conducted at weekly intervals from September 13 to October 17. Except for one flock of sheep (IP5), all others tested negative. All premises with cattle that were not within the Intensive Patrol Area were visited every other day for clinical inspection and no evidence of clinical disease was found. All premises with pigs were inspected every day and no evidence of clinical disease was identified. Surveillance within the protection zone was completed on October 17.

On October 17, the protection zone was lifted and incorporated into the wider surveillance zone. Surveillance activities in this surveillance zone commenced on October 24 and were completed on November 4. A total of 663 premises in the surveillance zone held susceptible livestock, all of which were visited. Blood samples were tested from 4,681 sheep, 491 goats, and 15,734 cattle, all with negative results.

Additional Surveillance

Abattoir Surveillance

Over 6 million susceptible animals were inspected at slaughter in Great Britain between July 30 and October 28. Detailed ante-mortem inspections were conducted on any animal showing signs of lameness or unwillingness to move, or any animal demonstrating excessive salivation. Post-mortem inspections included close examination of the mouth and feet of 100% of susceptible animals. No cases of FMD were identified at abattoirs.

Welfare Visits

DEFRA's Animal Health Agency carries out routine welfare visits to farms and markets. These provide an opportunity to check livestock for signs of notifiable disease. Between August 4 and November 23, 2007, a total of 506 on-farm visits with 1,038 inspections were conducted and 260 market visits with 562 inspections were completed. No cases of FMD were detected.

Veterinary Inspections for Movement Licensing

Between August 16 and October 18, health certificates were issued confirming no signs of FMD for the movement of approximately 3 million pigs and over 10,000 cattle.

On-Farm Sheep and Goat Survey

In accordance with Community requirements, an annual on-farm survey is conducted to demonstrate freedom from contagious agalactia due to *Mycoplasma agaltactiae* and other mycoplasmas. During the period July 14, 2007 and November 23, 2007, over 16,000 sheep and 358 goats were sampled for mycoplasma testing. No suspected clinical signs of FMD were observed at the time of testing.

Bovine Tuberculosis Tests

Periodic tuberculosis testing is conducted on all established herds. During the period July 14, 2007 to November 23, 3007, over one million cattle were inspected while being tested. No clinical signs were observed at the time of testing.

National Scrapie Plan and Genotyping Scheme

Between July 14, 2007 and November 23, 2007, a total of 67,000 sheep were blood sampled for genotyping. No suspected clinical signs of FMD were observed at the time of sampling.

Surveillance for FMD Freedom

In November 2007, surveillance was conducted to demonstrate the absence of circulating FMD virus in accordance with OIE guidelines (Appendix 3.8.7 of the Terrestrial Animal Code). Random serological surveillance of cattle herds and sheep and goat flocks was carried out in within defined distances from the Pirbright site. This surveillance was designed on a sample size that will detect 1% prevalence of the disease with 95% confidence among the herds and flocks.

A total of 305 premises were visited where 11,807 animals were bled and tested with negative results for FMD (Table 1). No disease was detected. In combination with the total number of blood samples tested during the August and September clusters, the grand total number of blood samples that tested negative was 60,036.

Table 1: Sampling of premises within defined distances from the Pirbright site.

Distance from Pirbright Site	20-30 km	30-40 km	40-90 km	90-150 km
Number of premises sampled	51	52	50	152
Number of blood samples taken per species				
Cattle	909	984	693	1881
Sheep	1152	779	1666	3563
Goats	60	15	6	99
Total	2121	1778	2365	5543

Investigations into the Source of the Outbreak

DEFRA established that the virus strain causing FMD on the first infected premises was O1 BFS67 (also known as O_1 BFS 1860/67UK). This is a laboratory strain not naturally found in the environment and one that was being used by all three occupants of the Pirbright site prior to the first outbreak. The Pirbright occupants included the Institute of Animal Health (IAH), a publicly-funded research organization that serves as the

Community Reference Laboratory for FMD; Merial Animal Health Ltd., a global commercial pharmaceutical company that manufactures vaccines for a number of animal diseases, including FMD; and Stabilitech Ltd., a privately owned company involved in developing technologies for the storage of vaccines and other biological materials in a dry state at ambient temperatures. It should be noted that this group of facilities is the only entity in the UK that handles or stores the FMD virus.

Great Britain's Health and Safety Executive (HSE), which is responsible for the enforcement of health and safety laws, was tasked to lead an investigation into biosecurity issues at the Pirbright facility. HSE's job was to lead a team to investigate:

- Potential breaches of biosecurity at the Pirbright site;
- Whether such breaches may have led to release of any specified animal pathogen;
- Whether any such breaches had been rectified to prevent future incidents.

A multidisciplinary, cross-government team including representatives from HSE, DEFRA, the Veterinary Medicines Directorate and the Environment Agency, conducted on-site investigations on August 5, 6 and 7, 2007.

HSE's final report [12] was published on September 7, 2007. The major findings of these investigations are summarized below.

- Liquid waste from the Merial facility is subjected to chemical treatment before it enters the effluent drainage system. This treatment utilizes citric acid concentrations and holding periods that exceed those recommended for the inactivation of FMD virus. However, chemical treatment may not be completely effective in inactivating the virus when the waste contains large amounts of organic matter and cellular debris. Although the effluent from the Merial laboratory is subjected to secondary treatment before it is discharged into the main sewer, it flows for some distance in underground pipe work before it reaches the secondary treatment plant.

- It is likely that live FMD virus entered the effluent drainage system from the Merial facilities during the period covered by the investigation, i.e., July 7 to July 26, 2007.

- The existing effluent drainage system does not provide adequate containment against the release of pathogens, and it is likely that live virus was released from the drainage system into the surrounding soil between July 20 and July 26.

- Construction activities occurring around the effluent drainage system resulted in the disturbance and movement of soil during the time period covered by the investigation. It is likely that this soil was contaminated with live FMD virus.

- It is likely that soil and/or materials contaminated with virus were removed from the Pirbright site between July 20 and July 25.

- It is likely that vehicles contaminated with this soil drove down a specific roadway that is in close proximity to the first infected premises. This occurred within the time period that DEFRA determined to be the most likely period of initial exposure of cattle on IP1.

The recommendations of the HSE report are reproduced below.

- We recommend that the required standards of containment for animal pathogens should be clearly documented to facilitate the regulatory process and that a review is completed to contrast the actual regulatory position for animal pathogens with human pathogens to make sure the position is justified.

- We recommend review of arrangements for setting and monitoring safe operating practices where work is subcontracted under a single license operating under the Specified Animal Pathogens Order (SAPO) with responsibilities clearly defined between the license holder and the subcontractor.

- We have concerns about the suitability of continued use of the upper south wing of the IAH laboratory, which is also used by Stabilitech for high containment work. In our view, it does not meet the requirement for SAPO 4 and we recommend that remedial work be carried out at the facility.

- We have concerns about filter arrangements throughout the IAH/Stabilitech facility where banks of HEPA filters are tested as a single unit leading to possible undetected failures. We recommend consideration given be to changing the siting and testing arrangements.

- We recommend review of the appropriateness of chemical treatment for sterilizing liquid waste containing SAPO Category 4 pathogens. It is our experience that chemical treatments, while reducing the amount of pathogen in the liquid, may not render the liquid completely pathogen-free.

- We recommend the effluent drainage system on the Pirbright site is improved to ensure high level SAPO requirements are met. In addition we also recommend better record keeping, maintenance and monitoring regimes in relation to the effluent drainage system.

- We recommend tighter controls of vehicle and human movement on the IAH site.

Actions Taken as a Result of the Pirbright Investigation

License authority to handle live FMD virus in all facilities on the Pirbright site was suspended as soon as the possible link between the site and the outbreak of FMD became apparent. In addition, access to the area around the effluent drainage system and all construction activities were suspended on August 8.

As a result of HSE's findings, which were initially released on August 7, the following key actions were taken in respect to biosecurity:

a) Extensive remedial work was undertaken on the draining system on the Pirbright site in August. The system was tested in early November by two independent, accredited engineering companies and found to be fully contained.

b) A heat treatment system was installed within the vaccine production plant to ensure that any waste potentially contaminated with FMD virus is subject to heat inactivated at the source, so that the risk of viable virus being discharged into the contained drains is as low as practicably possible.

c) All procedures conducted at the IAH facility were internally reviewed to minimize the risk of generating aerosols within the contained laboratories and to ensure inactivation of virus in liquid waste prior to its discharge to the contained drains. A peer review of this work by independent experts is due to be released in February 2008.

d) All effluent from the contained drains is subjected to further chemical treatment, which is monitored on a daily basis. Although this process was in place prior to the incident, the fact that preliminary treatment of liquid waste had failed to inactivate FMD virus prior to discharge into the effluent drainage system created a heightened awareness of the importance of the secondary treatment.

e) All HEPA filters in both the IAH and Merial facilities were tested by accredited, independent specialists, to confirm their integrity.

f) Site security has been strengthened, including the erection of secure fencing to separate the vaccine and research facilities.

As stated above, license authority to handle live FMD virus in all facilities on the Pirbright site was suspended in August 2007. Permission to restart work in the various laboratories was given incrementally, as soon as the Government was satisfied that the necessary measures were in place to eliminate the risk of further virus release as far as practically possible.

License authority for vaccine production was restored on November 6, 2007, but had to be suspended on November 20 when the company reported suspicion of an unintended release of virus into the contained drainage system. An inspection team visited the site on November 21, and concluded that FMD virus had not been released into the environment. On November 22, the Secretary of State made a written statement to Parliament regarding this incident, which was believed to have involved a leaking valve within the vaccine production system. The incident was contained by the rigorous biosecurity safety mechanisms in place.

In addition to the extensive work on strengthening the existing biosecurity at the Pirbright site, an independent review of biosecurity considerations relating to a proposed new development at the research facility is also underway, together with a separate review of proposed future management and governance arrangements.

All other veterinary and medical high containment laboratory facilities in the UK were advised of all relevant issues arising from the Pirbright investigation through a Safety Alert issued jointly by Defra and the HSE on September 7, 2007. The alert required laboratories to ensure that their facilities and procedures addressed these issues adequately. It also announced a program of inspections to these laboratories. The first phase of the inspection program focused on containment level 4 facilities and was completed in November 2007 and found no breaches of legislation. A 12 month program of inspections of containment level 3 laboratories began in January 2008.

Risk factors applicable to Surrey County, England

The occurrence of FMD outbreaks in the UK posed a risk to the United States from importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine exported from Surrey County, England [1]. APHIS implemented an import prohibition to address that risk.

While eradication of disease should mitigate immediate risk from the outbreaks that occurred, the FMD virus potentially could remain in circulation if diseased animals were not detected or if the virus survives in contaminated soil or on other fomites. Reintroduction is also possible if accidental releases of live virus from the laboratory and vaccine production facilities were to subsequently occur.

APHIS cites the prompt actions by the UK veterinary authorities to control animal movements and to aggressively conduct epidemiological investigations as factors in limiting the spread of disease. The surveillance programs conducted in response to the outbreaks indicate that the diseased animals are not likely to exist in Surrey County, England. The implementation of corrective measures at the Pirbright laboratory and vaccine production center, the identified source of the virus responsible for the Surrey County outbreaks, as well as the enhanced biosecurity awareness and inspection programs at laboratories throughout the UK, give APHIS confidence that the risk of accidental release of live virus into the environment has been appropriately addressed.

Release Assessment Conclusion

APHIS concludes that the eradication and control measures undertaken by the UK in response to the 2007 outbreaks were effective and that FMD-infected animals are not likely to exist in Surrey County, England. APHIS could identify no additional risk factors currently applicable to consideration of Surrey County, England as FMD-free. Therefore APHIS considers the risk of introducing FMD into the United States with the

resumption of importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England to be low.

Exposure Assessment [13-17]

An exposure assessment as defined by the OIE describes the biological pathway(s) necessary for exposure of animals and humans in an importing country to the hazards released from a given risk source, and estimates the probability of the exposure(s) occurring [9]. APHIS' regulatory authority is limited to animal health; therefore potential risks to animals are the primary focus of this evaluation.

APHIS considers that the most likely pathway of exposure of domestic livestock to FMD virus in meat (pork or beef) and meat products is through feeding of contaminated food waste to swine. Other exposure pathways are more direct and include contact with imported infected live animals or contact with infected genetic material.

Waste-feeding practices in the United States

The likelihood of exposure of susceptible species to FMD virus -infected meat was evaluated in previous studies conducted by APHIS. In 1995, APHIS conducted a pathway analysis to estimate the likelihood of exposing swine to infected waste. The analysis included two pathways for exposure of swine to contaminated waste; namely, exposure associated with illegal household imports, and exposure associated with legal imports. The latter is the exposure pathway that would be applicable to importing meat or meat products from the Surrey County, England. With 95% confidence, APHIS estimated that 0.023% or less of plate and manufacturing waste would be inadequately processed prior to feeding to swine. Based on this fraction, less than 1 part in 4,300 (reciprocal of 0.023%) of imported meat is likely to be fed to swine as inadequately cooked waste.

APHIS conducted a survey in 2001 of the U.S. swine waste-feeding sector to update a similar study done in 1994. Based on this survey, APHIS Veterinary Services estimated that the proportion of plate and manufacturing waste fed to swine diminished by about 50% between 1994 and 2001 due to a decrease in the number of waste-feeding premises. The study also found that:

1. Several more states prohibited feeding food wastes to swine;
2. The number of waste-feeding premises in the continental United States decreased by 40.5% from 1994-2001, and in Hawaii and Puerto Rico decreased by 37.5% and 52.3%, respectively; and
3. Institutions and restaurants provide nearly 90% of all plate waste fed to swine.

APHIS considers that prohibiting the feeding of unprocessed plate waste to swine has further contributed to the reduction of waste-feeding to swine. In this regard, waste-feeder operations must be licensed and inspected regularly by USDA inspectors (9 CFR 166). The licensing process requires that producers adequately cook the waste fed to swine according to methods designed to reduce the probability of survival of foreign animal disease agents in the waste.

Based on the 1995 estimate that a very small proportion of food waste is inadequately processed prior to feeding to swine, and the substantial reduction in waste-feeding operations in recent years, APHIS considers the likelihood of exposure of susceptible swine to FMD virus through inadequately processed food waste to be low. Based on the conclusion of the release assessment that diseased animals are not likely to exist in Surrey County, England, APHIS further considers the probability of exposure of susceptible swine to these viruses through inadequately cooked FMD-infected meat from Surrey County, England, to be very low.

Imported live animals

The likelihood of exposure of susceptible species to infected live animals was evaluated by briefly reviewing virus persistence and shedding in live swine and ruminants, as well as standard import requirements for these species. The exposure assessment focuses on breeding animals since APHIS considers transportation costs to be burdensome for export of other live animals (e.g. feeder pigs or cattle) to the United States from Surrey County, England. Additionally, it should be noted that the importation of all live ruminants and ruminant products are currently prohibited due to bovine spongiform encephalopathy (BSE). Similarly, APHIS considers exposure of a susceptible U.S. animal population to illegally imported infected live animals from the Surrey County, England, to be highly unlikely.

Upon exposure to FMD, up to 50% of ruminant animals may become carriers of FMD virus. The maximum reported duration of the carrier state is 3.5 years in cattle, 9 months in sheep, and 4 months in goats. The duration of carrier state depends on the host species and the strain and serotype of the FMD virus but presents at least a theoretical risk of introducing FMD into a susceptible population.

Consequently, APHIS considers this potential pathway for disease introduction to carry an inherently high unmitigated risk. Current U.S. regulations require certification that ruminants and swine have been kept in a region entirely free of FMD for 60 days prior to export (9 CFR 93.405 and 93.505) and also require a minimum quarantine of 30 days for most imported ruminants (9 CFR 93.411) and 15 days for all imported swine (9 CFR 93.510) from the date of arrival at the port of entry. These requirements serve to partially mitigate the risk of exposure by increasing the probability of disease detection.

Based on the conclusion of the release assessment that diseased animals are not likely to exist in Surrey County, England, APHIS considers the probability of exposure of susceptible U.S. animals to FMD virus via infected ruminants and swine from the Surrey County, England, to be low.

Imported genetic material

Genetic materials have been implicated in the introduction of foreign animal disease into susceptible populations, as well as the spread of established disease epidemics over

considerable distances. FMD virus may be present in semen up to 4 days before clinical signs become apparent.

Based on the extended period of survival of FMD virus in frozen semen, APHIS considers there is a likelihood of exposure of susceptible animals to this virus in infected semen. However, based on the conclusion of the release assessment that diseased animals are not likely to exist in Surrey County, England, APHIS considers exposure of a susceptible U.S. animal population to imported infected semen or embryos from the Surrey County to be highly unlikely.

Exposure Assessment Summary

Based on pathway analyses, APHIS concluded that the likelihood of exposure of susceptible swine to FMD virus through inadequately processed food waste to be low. This conclusion is supported by evidence that only a very small proportion of food waste is inadequately processed prior to feeding to swine and the substantial reduction in waste-feeding operations in recent years. Furthermore, based on the conclusion of the release assessment that diseased animals are not likely to exist in Surrey County, England, APHIS considers the probability of exposure of susceptible swine to these viruses through inadequately cooked infected meat from Surrey County, England to be low.

In addition, APHIS considers the likelihood of exposure of susceptible U.S. ruminants or swine to FMD virus via infected ruminants or swine from Surrey County, England, to be low. Current U.S. regulations require certification that ruminants and swine have been kept in a region entirely free of FMD for 60 days prior to export (9 CFR 93.405 and 93.505) and also require a minimum quarantine of 30 days for most imported ruminants (9 CFR 93.411) and 15 days for all imported swine (9 CFR 93.510). These requirements serve to partially mitigate the risk of exposure by increasing the probability of disease detection prior to export and during quarantine in the United States.

Based on the conclusion of the release assessment that diseased animals are not likely to exist in Surrey County, England, APHIS considers exposure of a susceptible U.S. animal population to imported infected semen or embryos from the Surrey County to be highly unlikely.

Ultimately, the requirements in 9 CFR 94.11 mitigate the risks associated with less restrictive trade practices by (1) restricting the sourcing of ruminants meat for export; (2) prohibiting commingling of live animals, meat, or meat products for export with such commodities from regions not considered free of these diseases; and (3) requiring exporting slaughter establishments to be approved by USDA, Food Safety and Inspection Service. In addition, an official veterinarian of the exporting country must certify that these conditions have been met.

Consequence Assessment [17-31]

A consequence assessment describes the biologic and economic consequences of introducing the hazards under consideration into the United States. This consequence assessment addresses both direct and indirect consequences as recommended by the OIE.

Although any introduction of FMD would be catastrophic, the precise magnitude of the biologic and economic consequences following an introduction of FMD virus would depend on the location of the introduction, the virus serotype introduced, the rate of virus spread and whether other environmental conditions at the introduction site that might facilitate this spread, ability to detect the disease rapidly, livestock demographics and movement patterns, and the ease of employing eradication procedures. In addition, depending on the extent of export of livestock and their products, trade restrictions imposed by trading partners may result in severe economic consequences.

Direct consequences include effects of the disease on animal health and the subsequent production losses, the total costs of control and eradication, the effect on the environment, and public health consequences. Indirect consequences include impacts on international trade and associated domestic consequences.

Effects on animal health and production

FMD causes significant distress and suffering to animals regardless of the size and sophistication of their livestock unit. Very high mortality rates in young animals can occur, particularly among pigs and sheep. In pigs, Dunn and Donaldson (1997) estimated a general mortality rate of 40% for two outbreaks in Taiwan in 1997. Geering (1967) cites mortality rates of 40, 45 and 94% of lambs in several outbreaks. Mortality in older animals occurs less frequently but may be significant with certain virus strains.

FMD causes significant losses in the production capacity of affected animals. Productivity losses of 10 to 20 percent are reported in FMD-infected livestock if the disease is allowed to run its course. For example, the drop in milk yield of dairy cattle averages approximately 25% per year. In addition, FMD can cause reduction in the growth rate of animals raised for meat. According to Doel (2003), estimates vary considerably but one study has indicated that cattle would require approximately 10-20% longer to reach maturity. The comparatively greater severity of FMD in pigs would imply at least similar losses to those described for cattle.

Control and eradication costs

The overall cost of control and eradication depends on the mitigation or policy option chosen to control and eradicate the disease. Potential costs include disease control measures such as imposing quarantine measures and movement controls, direct costs related to stamping out of affected and other herds, indemnity payments, vaccination costs, surveillance and laboratory testing amongst others. For countries like the United States that have a substantial export market for livestock and livestock products, the

preferred option for control and eradication has traditionally been to stamp-out infected herds without the use of vaccine.

The U.S. policy for most significant foreign animal disease emergencies is to follow strict quarantine measures and stamping-out of infected and contact herds with ongoing assessment for the need for and implementation of strategic vaccination. It is difficult to predict the extent of any outbreak that might occur if FMD virus was introduced into the United States, but the cost of control, eradication and compensation would likely be significant.

A few studies have estimated the potential consequences of an FMD outbreak in the United States. In fact, results from a FMD simulation model were used to estimate the direct costs associated with indemnity, slaughter, cleaning and disinfecting livestock premises for various vaccination and eradication strategies to control transmission of FMD virus in a cattle population of 2,238 herds and 5 sale yards located in 3 counties of California. The study found that mean herd indemnity payments were USD 2.6 million and USD 110,359 for dairy and non-dairy herds, respectively. Cleaning and disinfection costs ranged from USD 18,062 – 60,205 per herd. The mean vaccination cost was USD 2,960 per herd and the total eradication cost ranged from USD 61 million – 551 million depending on eradication strategy.

At the national level, a comprehensive study was conducted to assess the potential economic impact of FMD in the United States. The study estimated the direct costs (control and eradication program costs) and increased costs borne by consumers of FMD introduction over a 15-year period (1976-1990). For this study, and using the Consumer Price Index to update to 2001, the estimated total cost of a strict quarantine and slaughter policy was USD 34.4 million.

Effect on the environment

Environmental effects have been considered under applicable environmental review laws in force in the United States. These are considered in a separate, but related, environmental assessment conducted for certain regions of the EU. The environmental assessment complies with the National Environmental Policy Act (NEPA) and implementing regulations [26].

Effect on public health

FMD may rarely affect humans. The number of cases reported is so small when compared with the number of persons exposed that FMD is generally not considered a threat to humans. FMD virus has been isolated and typed in only 40 patients during the last century. Symptoms in humans are mostly mild and mainly include fever, and blisters on the hands, feet, mouth, and tongue. Patients usually recover within a week after the last blister formation.

Indirect consequences

In addition to the direct costs of FMD introduction, impacts on international trade and related domestic consequences need to be considered. Export losses due to restrictions imposed by trade partners on FMD-susceptible animals and products can run into billions of US dollars. The value of U.S. exports of beef products alone, which would be immediately lost, was over US$3 billion in 2001. The impact of an outbreak of FMD on the rural and regional economic viability, including businesses reliant on livestock revenue, could also be substantial.

In 2002, Paarlberg et al. conducted a study to estimate the potential revenue impact of an FMD outbreak in the U.S. similar to the one that occurred in the UK. The study suggested that greatest impact on farm income would be due to loss of export markets and the decrease in demand by consumers. For example, losses of gross revenue for the animal sector were as follow: cattle (17%), beef (20%), milk (16%), swine (34%), pork (24%), sheep and lambs (14%), and sheep and lamb meat (10%). Thompson et al (2002) estimated the loss of about 20% of the estimated total income from farming in 2001 because of the FMD outbreak in the UK.

Japan, Korea and Mexico constitute the three major U.S. export markets for ruminant products. The approximated value of lost exports to these three ruminant markets would total $3 billion annually if trade restrictions were enforced against the U.S.: Japan ($1.2 billion); Mexico ($1.12 billion); and South Korea ($712 million). Indirect economic losses to U.S. firms that support ruminant exports to these three markets would equal an additional $2.5 billion annually. The magnitude of these values reflects both animal and product exports.

More than 33 thousand full-time U.S. jobs, accounting for almost $1 billion in wages annually, could be jeopardized by loss of these three markets. In the longer term, if trade restrictions persisted and alternative export markets did not develop, the U.S. ruminant production sector could contract, allowing other supplying countries to establish trade relationships in the absence of U.S. supply.

Other losses due to restrictions on live swine, pork, and pork products are likely to be significant as well. The U.S. exports of pork and pork products are estimated at $2.2 billion dollars in 2006. Since the U.S. exports only small amounts of lamb and mutton, economic losses associated with these commodities are not likely to be significant compared to cattle and swine.

Risk Estimation

APHIS concludes from its release assessment that the eradication and control measures undertaken by the UK in response to the 2007 outbreaks were effective and that FMD-infected animals are not likely to exist in Surrey County, England. APHIS could identify no additional risk factors currently applicable to consideration of Surrey County, England as FMD-free. Therefore APHIS considers the risk of introducing FMD into the United States with the resumption of importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England to be low.

According to OIE guidelines, if the release assessment indicates that there is no significant risk of introduction, the risk assessment may conclude. However, APHIS continued its analysis in the interest of completeness and conducted exposure and consequence assessments.

Regarding the likelihood of exposure, APHIS considers three likely pathway of exposure of domestic livestock to FMD virus: the feeding of FMD virus -contaminated food waste to swine, contact with imported infected live animals, and contact with infected genetic material. Based on the unlikely prospect that FMD-infected animals exist in Surrey County, England and on the mitigating effects of waste feeding and import regulations associated with these pathways, APHIS concluded that the likelihood of exposure from importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England to be low.

APHIS continued its assessment further and conducted a consequence assessment that addressed the potential effects of an FMD outbreak on animal and public health, as well as associated economic considerations. Consequences of human exposure from FMD are negligible. Conversely consequences on animal health are high, although effective disease surveillance and control measures could reduce the consequences by reducing the extent of spread. Effects on the environment have been considered in separate reviews in compliance with applicable federal environmental laws and regulations; however, consequences to the environment are considered to be within the scope of APHIS resources and authority to manage adequately.

Although consequences of an FMD outbreak are potentially substantial, the likelihood of an outbreak occurring from exposure of domestic susceptible animal populations to ruminants and swine or the fresh meat or other animal products of ruminants and swine imported from Surrey County, England is low.

In summary, APHIS concludes that the risk of introducing FMD into the United States with the resumption of importation of ruminants and swine and the fresh meat and other animal products of ruminants and swine from Surrey County, England is low.

References

1. OIE (2007). Office International des Epizooties (OIE), Disease Information (weekly reports): http://www.oie.int/wahid-prod/public.php?page=event_summary&reportid=5869

2. Change in Disease Status of Surrey County, England, Because of Foot-and-Mouth Disease. Federal Register, Wednesday, January 30, 2008. 73(20): pp. 5424-5426.

3. Foot and Mouth Disease, Internet web page. Government of the United Kingdom, Department for Environment Food and Rural Affairs (DEFRA). http://www.defra.gov.uk/animalh/diseases/fmd/default.htm

4. Colgrove, G., Personal communication: Follow-up to January 23, 2008, technical meeting with DEFRA officials in London, England. January 23, 2008.

5. Council Directive 2003/85/EC of 29 September 2003 on Community measures for the control of foot-and-mouth disease repealing Directive 85/511/EEC and Decisions 89/531/EEC and 91/665/EEC and amending Directive 92/46/EEC. Official Journal of the European Communities, Nov 22, 2003. L 306: p. 0001 - 0087. http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0085:EN:HTML

6. Office International des Epizooties (OIE), Terrestrial Animal Health Code, OIE Listed Diseases. Article 2.1.1.3. http://www.oie.int/eng/normes/mcode/en_chapitre_2.1.1.htm

7. Title 9, Code of Federal Regulations (9 CFR), part 94, Rinderpest, foot-and-mouth disease, fowl pest (fowl plague), Exotic Newcastle disease, African swine fever, classical swine fever, and bovine spongiform encephalopathy: Prohibited and restricted importations.

8. Title 9, Code of Federal Regulations (9 CFR), section 94.2, Application for recognition of the animal health status of a region.

9. Office International des Epizooties (OIE), Terrestrial Animal Health Code - 2007, Part 1, Section 1.3. Risk Analysis. http://www.oie.int/eng/normes/mcode/en_titre_1.3.htm

10. APHIS Evaluation of FMD Status of The Netherlands and Northern Ireland, October 2001, United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services. https://web01.aphis.usda.gov/db/mtaddr.nsf/2f5c87c0140172cb852564bf0046d1e2/d41e2918f21a9b7185256b10005deab4?OpenDocument

11. APHIS Evaluation of FMD Status of Great Britain (England, Scotland, Wales, and the Isle of Man), May 2002, United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services. https://web01.aphis.usda.gov/db/mtaddr.nsf/2f5c87c0140172cb852564bf0046d1e2/5ce6d790a20cc93485256bf400649d29?OpenDocument

12. Logan, P. Health and Safety Executive (HSE), Government of the United Kingdom. "Final report on potential breaches of biosecurity at the Pirbright site 2007," December 2007. http://www.hse.gov.uk/news/archive/07aug/finalreport.pdf

13. USDA, APHIS, VS, Centers for Epidemiology and Animal Health, Risk Assessment of the Practice of Feeding Recycled Commodities to Domesticated Swine in the U.S. 1995.

14. USDA, APHIS, VS, Centers for Epidemiology and Animal Health, Pathway assessment of foot-and-mouth disease (FMD) risk to the United States: an evaluation in response to international FMD outbreaks in 2001. 2001.

15. USDA, APHIS, VS, Centers for Epidemiology and Animal Health, 2001 waste-feeder survey (unpublished data). 2001.

16. USDA, APHIS, VS, Unpublished epidemiological reports. 2003.

17. Alexandersen, S., et al., The pathogenesis and diagnosis of foot-and-mouth disease. J Comp pathol, 2003a. 129(1): p. 1-36.

18. Bates, T.W., T.E. Carpenter, and M.C. Thurmond, Benefit-cost analysis of vaccination and preemptive slaughter as a means of eradicating foot-and-mouth disease. Am J Vet Res, 2003. 64(7): p. 805-12.

19. Doel, T.R., Optimization of the immune response to foot-and-mouth disease vaccines. Vaccine, 1999. 17(13-14): p. 1767-71.

20. Dunn, C.S. and A.I. Donaldson, Natural adaption to pigs of a Taiwanese isolate of foot and mouth disease virus. Vet Rec, 1997. 141: p. 174-75.

21. Geering, W.A., Foot and mouth disease in sheep. Aust Vet J, 1967. 43: p. 485-89.

22. James, A.D. and J. Rushton., The economics of foot and mouth disease. Rev Sci Tech, 2002. 21(3): p. 637-44.

23. McCauley, E.H. et al. (1979). Potential economic impact of foot-and-mouth disease in the United States. St. Paul, Minnesota: U.S. Government Printing Office.

24. McDowell, R. Economic impacts of FMD adjusted from 1976 dollars to March 2001 dollars by Consumer Price Index. 2002.

25. Power, A.P. and S.A. Harris, A cost-benefit evaluation of alternative control policies for foot and mouth disease in Great Britain. J Agri Econ, 1973. 24: p. 573-96.

26. National Environmental Policy Act (NEPA) of 1969, as amended (40 U.S.C. 4321 et seq.) AND regulations of the Council on Environmental Quality for implementing the procedural provisions of NEPA (40 CFR parts 1500-1508) AND USDA regulations implementing NEPA (7 CFR part 1b) AND APHIS' NEPA Implementing Procedures (7 CFR part 372). 1969.

27. FAS. U.S. beef, pork and poultry trade charts. http://www.fas.usda.gov/dlp/tradecharts/. 2006.

28. Green, J.W. and J.L. Grannis. Economic impact of alternative management strategies for regulating Canadian ruminant/product imports. Unpublished report. 2003. Centers for Epidemiology and Animal Health.

29. Paarlberg, P.L., J.G. Lee, and A.H. Seitzinger. Potential revenue impact of an outbreak of foot-and-mouth disease in the United States. J Am Vet Med Assoc, 2002. 220(7): p. 988-92.

30. WHO. Foot and mouth disease: consequences for public health.

31. Woodbury, E.L. A review of the possible mechanisms for the persistence of foot-and-mouth disease virus. Epidemiol Infect. 1995. 114(1): p. 1-13.

APPENDIX – Epidemiologic characteristics of foot-and-mouth disease (FMD)

Etiologic Agent
Family *Picornaviridae*, Genus *Aphthovirus*, types O, A, C, SAT 1, SAT 2, SAT 3, and Asia 1.

Status in the United States
FMD virus (FMDV) was eradicated from the United States in 1929.

Epidemiology
FMD is a highly communicable disease of cloven-hoofed animals caused by an *Aphthovirus* of the family Picornaviridae. FMD has seven immunologically distinct serotypes (O, A, C, SAT1, SAT2, SAT3, and Asia 1). The O, A, and C serotypes have historically been found in South America [1]. Research indicates that one serotype does not confer protective immunity against the other six, thus a disease outbreak can be caused by one serotype or a combination of serotypes [2].

FMDV can be transmitted by direct or indirect contact or aerosol. Fomites (such as feed, drinking water, tools, animal products, as well as human clothing, transportation vehicles, rodents, stray dogs, wild animals, and birds) can transmit FMD over long distances. The five main elements that influence the extent of FMD spread are: (1) the quantity of virus released; (2) the means by which the virus enters the environment; (3) the ability of the agent to survive outside the animal body; (4) the quantities of virus required to initiate infection at primary infection sites; and (5) the period of time the virus remains undetected [3, 4].

The incubation period of the FMDV is 2-14 days in cattle, depending on the viral strain and dose and the level of susceptibility of the animal [5]. Morbidity in unvaccinated herds can be high, but mortality usually does not exceed 5 percent. If it occurs during the calving season, calf mortality can be considerable [6]. Young claves may even die before the development of clinical signs usually because the virus attacks the heart muscles [5].

The respiratory tract is the usual route of infection in species other than pigs. Infection can also occur through abrasions of the skin or mucous membranes. In cattle and sheep, the earliest sites of virus infection and possibly replication appear to be in the mucosa and the lymphoid tissues of the pharynx. Following initial replication in the pharynx, the virus then enters the bloodstream. Viremia in cattle lasts for 3 to 5 days; as a result, the virus spreads throughout the body and establishes sites of secondary infections [7].

Pigs are less susceptible to aerosol infection than ruminants and the usual route of infection is through the ingestion of FMDV contaminated products, direct contact with infected animals or a heavily contaminated environment. The incubation period in pigs will vary with the strain dose and route of infection. Exposure to an initial low dose of virus may result in clinical signs be mild enough, such as lameness and coronary band lesions, to go undetected until the infection s is established in the herd and transmission

by direct contact between infected and susceptible animals is rapid and may involve aerosol, oral , mucosal transmission. [Kitching 21(3) 513-518]

FMDV localizes in various organs, tissues, body fluids, bone marrow, and lymph nodes [8, 9]. Viral replication may reach peak levels as early as 2 to 3 days after exposure [10, 11]. Virus titers differ in different organs or tissues. Some tissues, such as the tongue epithelium, have particularly high titers. Recent data indicate that the most viral amplification occurs in the stratified, cornified squamous epithelia of the skin and mouth (including the tongue). Although some viral replication also occurs in the epithelia of the pharynx, the amount of virus produced there is apparently much less than the amount produced in the skin and mouth during the acute phase of the disease. By comparison, the amount of virus (if any) produced in other organs like salivary glands, kidneys, liver, and lymph nodes is negligible [10, 11].

Immunity to FMD is primarily mediated by circulating antibodies [12]. The host reaction, including antibody production, occurs from 3 to 4 days after exposure and usually clears the virus, except in carriers. In infected pigs, the virus is cleared in less than 3 to 4 weeks. In contrast, around 50 percent or more of cattle will develop a low-level persistent infection, localized to the pharynx [13-15]. According to Alexandersen (2002) [12], a model for progression of infection can be described as follows: first, virus exposure and accumulation of virus in the pharyngeal area are followed by initial spread through regional lymph nodes and via the blood stream to epithelial cells. This is followed by several cycles of viral amplification and spread [12].

Clinical signs in cattle during acute infection include fever, profuse salivation, and mucopurulent nasal discharge. The disease is characterized by development of vesicles on the tongue, hard palate, dental pad, lips, muzzle, gum, coronary band, and interdigital spaces. Vesicles may develop on the teats. Affected animals loose condition rapidly, and there is a dramatic loss of milk production [5]. The animal usually recovers by 14 days post infection provided no secondary infections occur [7]. The most consistent clinical signs in pigs during acute infection is lameness with lesions around the coronary bands but with fever may be inconsistent. Pigs may develop vesicles on the tongue and snout but these may be less obvious than lesions seen in ruminants. The severity of clinical disease will depend on the age of the infected pig, adult swine may recover or become chronically lames while younger pigs, especially those less that 8 weeks of age may die acutely from myocarditis without showing any clinical signs [13].

Diagnosis of the disease relies heavily on recognizing clinical signs. In unvaccinated cattle and pigs, the clinical signs are obvious. However, in small ruminants the disease is often subclinical or is easily confused with other conditions. In addition, in endemic regions, clinical signs in partially immune cattle may be less obvious and could pass unnoticed [5]. Virus isolation and serotype identification are necessary for confirmatory diagnosis. The clinical signs of FMD are similar to those seen in other vesicular diseases. Differential diagnosis of vesicular diseases includes vesicular stomatitis, mucosal disease of cattle, bluetongue, rinderpest, and FMD. Serological diagnostic tests include the

complement-fixation test, virus neutralization test, and an enzyme-linked immunosorbent assay test. Other diagnostic tests include one- or two-dimensional electrophoresis of the viral DNA, isoelectric focusing of the viral structural proteins, or nucleotide sequencing of the viral RNA [4].

FMDV is a relatively resilient virus. It can survive up to 15 weeks in feed, 4 weeks on cattle hair, and up to 103 days in wastewater. The survival of the virus in animal tissues is closely associated with the acidity of that tissue. For example, in muscular tissues the acidity of rigor mortis, which occurs naturally, inactivates the virus. The production of lactic acid in these tissues during maturation is considered to be the primary factor for inactivation [16]. An acid environment where the pH is less than 6.0 will destroy the virus quickly [16, 17]. Several studies showed that in tissues where no acidification occurs (e.g., lymph nodes, bone marrow, fat, and blood), the virus may survive for extended times in cured, uncured, and frozen meat [9, 16-19]. Heating at 50° C [20] and up to 155° F [21] will inactivate the virus.

References

1. Hall, H., *Diseases and Parasites of Livestock in the Tropics, 2nd Edition.* Intermediate Tropical Agriculture Series, 1985: p. 41-46.
2. Kitching, R., et al., *Development of Foot-and-Mouth Disease Virus Strain Characterization-A Review*. Trop An Health Prod, 1989. **21**:p. 153-66.
3. Mann, J. and R.F. Sellers, *Foot and Mouth Disease*, in *Virus Infections of Vertebrates*, Z. Dinter and B. Morein, Editors. 1990, Elsevier. p. 903-12.
4. Thomson, G., *Foot-and-Mouth Disease*, in *Infectious diseases of livestock*, Coetzer, Thomson, and Tustin, Editors. 1994, Oxford University Press; Cape Town, South Africa. p. 825-52.
5. Kitching, R.P., *Clinical variation in foot and mouth disease; cattle*. Rev Sci Tech, 2002a. **21**(3): p. 499-504.
6. Seifert, H., *Foot-and-Mouth Disease*, in *Tropical Animal Health*. 1996, Kluwer Academic Publishers: London, Massachusetts. p. 418-31.
7. Woodbury, E.L., *A review of the possible mechanisms for the persistence of foot-and-mouth disease virus*. Epidemiol Infect, 1995. **114**(1): p. 1-13.
8. Sellers, R.F., *Quantitative aspects of the spread of foot-and-mouth disease*. Vet Bull, 1971. **41**(6): p. 431-39.
9. Cottral, G.E., *Persistence of foot-and-mouth disease virus in animals, their products and the environment*. Bull Off Int Epizoot, 1969. **70**(3): p. 549-68.
10. Alexandersen, S., M.B. Oleksiewicz, and A.I. Donaldson, *The early pathogenesis of foot-and-mouth disease in pigs infected by contact; a quantitative time-course study using TaqMan RT-PCR*. J Gen Virol, 2001. **82**(Pt 4): p. 747-55.
11. Oleksiewicz, M.B., A.I. Donaldson, and S. Alexandersen, *Development of a novel real-time RT-PCR assay for quantitation of foot-and-mouth disease virus in diverse porcine tissues*. J. Virol Methods, 2001. **92**(1); p. 23-35.

12. Alexandersen, S., Z. Zhang, and A.I. Donaldson, *Aspects of the persistence of foot-and-mouth disease virus in animals--the carrier problem*. Microbes Infect, 2002. **4**(10): p. 1099-110.
13. Kitching, R.P., *Identification of foot and mouth disease virus carrier and subclinically infected animals and differentiation from vaccinated animals*. Rev Sci Tech, 2002(b). **21**(3): p. 531-8.
14. Salt, J.S., T*he carrier state in foot and mouth disease--an immunological review*. Br Vet J, 1993. **149**(3): p. 207-23.
15. Zhang, Z.D. and R.P. Kitching, *The localization of persistent foot and mouth disease virus in the epithelial cells of the soft palate and pharynx*. J Comp Pathol, 2001. **124**: p. 89-94.
16. Cottral, G.E., B. F. Cox, and D.E. Baldwin, *The survival of foot-and-mouth disease virus in cured and uncured meat*. Am J. Vet Res, 1960. **21**: p. 288-97.
17. Henderson, W.M. and J.B. Brooksby, *The survival of foot and mouth disease virus in meat and offal*. J Hyg (Lond), 1948. **46**(4): p. 394-402.
18. Cox, B.F., G.E. Cottral, and D.E. Baldwin, *Further studies on the survival of foot and mouth disease virus in meat*. Am J Vet Res, 1961: p. 224-226.
19. Lasta, J., et al., *Combined treatment of heat, irradiation, and pH effects on the infectivity of foot-and-mouth disease virus in bovine tissues*. J Food Sci, 1992. **57**(1): p. 36-39.
20. Green, J.W. and J.L. Grannis, *Economic impact of alternative management strategies for regulating Canadian ruminant/product imports*. Unpublished report. 2003, Centers for Epidemiology and Animal Health.
21. Heidelbaugh, N. and J. Graves, *Effects of some techniques applicable in food processing on the infectivity of foot and mouth disease virus*. Food Tech, 1968. **22**: p. 120-124.